



## DEVELOPMENT OF NOVEL LOW-COST CARBON-BASED CO<sub>2</sub> SORBENTS

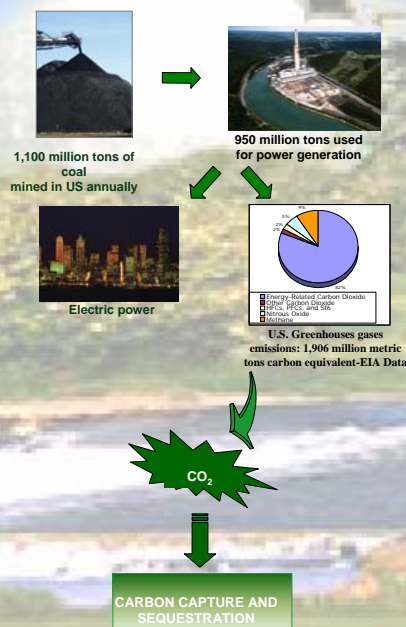
M. Mercedes Maroto-Valer\*, Zhe Lu, Zhong Tang, Yinshi Zhang

\*E-mail: mmm23@psu.edu ; Phone no: (814) 863 8265, Fax no: (814) 863 8892

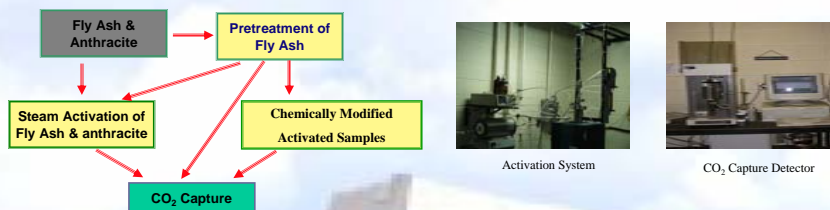
Department of Energy and Geo-Environmental Engineering and The Energy Institute, The Pennsylvania State University, 122 Hosler Building, University Park, PA 16802

### 1. INTRODUCTION

- Anthropogenic emissions have increased the CO<sub>2</sub> concentration on the atmosphere with over 30% compared to preindustrial levels. There is a general agreement in the scientific community that doubling the CO<sub>2</sub> emissions will have a serious detrimental effect on the environment.
- Most of these anthropogenic emissions are caused by fossil fuel utilization.
- Fossil fuels have been the main energy supplier in the US for over a century.
- Carbon capture technologies must be developed to achieve zero emissions
- Current chemical absorption technologies are very energy intensive. Physical and chemical adsorption processes for CO<sub>2</sub> capture using high-surface area solids have also been proposed. However, the sorbents used thus far are very expensive and hinder the economical viability of the process.
- Therefore, there is a need to find cost-effective precursors that can compete with expensive commercial sorbents.
- Activated carbon from fly ash carbon and anthracites are low-cost sorbents that can be used for CO<sub>2</sub> capture.



### 2. EXPERIMENTAL DESIGN



### 3. RESULTS AND DISCUSSION

Table 1. LOI (carbon content) and pore structure parameters of the studied samples: fly ash carbons (CC1 and FA1) and anthracite samples (PSOC-1468).

Samples	LOI, %	Surface area, m <sup>2</sup> /g		Total pore volume, ml/g	
		S <sub>int</sub>	S <sub>ext</sub>	V <sub>int</sub>	V <sub>ext</sub>
CC1	38	48	236	0.021	0.256
CC1-DEM	97	99	632	0.038	0.702
FA1	59	57	18	0.027	0.020
FA1-DEM	97	32	21	0.014	0.026
FA1-N1	99	189	20	0.094	0.024
AC-FA1	43	329	58	0.151	0.062
AC-FA1-DEM	89	704	159	0.318	0.172
AC-FA1-N1	97	1053	86	0.518	0.097
PSOC-1468-2.0	-	529	18	0.239	0.011
PSOC-1468-2.0	-	733	29	0.330	0.030
PSOC-1468-2.0	-	891	37	0.406	0.036
PSOC-1468-2.0	-	814	41	0.372	0.040

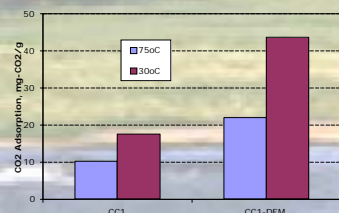


Figure 1. CO<sub>2</sub> adsorption capacities of the samples CC1 and CC1-DEM at 30°C and 75°C.

- At 30°C, the parent sample CC1 can adsorb around 17.5 mg CO<sub>2</sub>/g, while CC1-DEM can adsorb as much as 43.5 mg CO<sub>2</sub>/g.
- As expected from a physical adsorption process, the CO<sub>2</sub> adsorption capacities of both sample decreased to 10.2 mg CO<sub>2</sub>/g and 22.0 mg CO<sub>2</sub>/g for raw CC1 and CC1-DEM, respectively, when the temperature was raised from 30 to 75°C.

- The deashing step used can successfully concentrate the fly ash carbon, where the resultant samples have LOI values as high as 97.0% (FA1-DEM).
- The HNO<sub>3</sub> treatment resulted in an increase of the surface area of the samples (AC-FA1-N1), and also modified the pore size distribution of the activated sample, resulting in a more microporous sample (1.053m<sup>2</sup>/g and 0.518ml/g).
- The pretreatment significantly increased the surface area of activated carbon (387 m<sup>2</sup>/g for the activated sample AC-FA1, 863 m<sup>2</sup>/g for the activated deashed sample AC-FA1-DEM, and 1,139 m<sup>2</sup>/g for the HNO<sub>3</sub> treated sample AC-FA1-N1).
- The activated carbon made from anthracite by steam activation has highly developed microporous structure (PSOC-1468 series).
- The optimum activation condition for anthracites studied here was at 850°C and 3 hours, and the maximum surface area was 927m<sup>2</sup>/g.

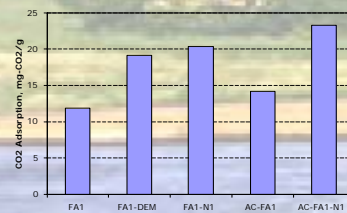


Figure 2. CO<sub>2</sub> adsorption capacities at 75°C for FA1 and its deashed and activated counterparts.

- Corresponding to its highest surface area and microporosity, AC-FA1-N1, has the largest CO<sub>2</sub> adsorption capacity of 23.2 mg CO<sub>2</sub>/g at 75°C, compared to those for samples FA1, FA1-DEM and their activated counterparts.

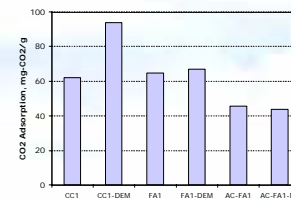
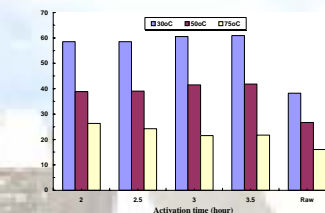
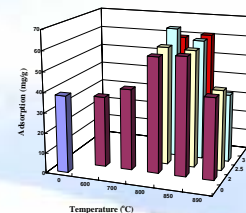


Figure 3. CO<sub>2</sub> adsorption capacities at 75°C for the PEI chemically impregnated samples.

After PEI impregnation, all samples have higher CO<sub>2</sub> adsorption capacities, especially for the PEI modified CC1-DEM that can adsorb as much as 93.6 mgCO<sub>2</sub>/g, compared to only 9.7 mgCO<sub>2</sub>/g for its non-impregnated counterpart.



- The adsorption is physical adsorption process.
- The adsorbed amount of CO<sub>2</sub> decreases with increasing of adsorption temperature.



- The anthracite with the highest CO<sub>2</sub> capture was activated at 800°C for 3 hours.
- The optimum activation temperature is 800-850°C for the activated anthracite that have the higher CO<sub>2</sub> capture capacity.

### 4. CONCLUSIONS

- The optimum activation condition for anthracite PSOC-1468 is 850°C and 3 hours.
- The highest CO<sub>2</sub> adsorption activated carbon of PSOC-1468 was made at the activation condition of 800°C and 3hrs.
- Samples with a carbon content ~97% can be concentrated from fly ash by using conventional acid digestion. The deashing process not only can remove the fly ash from unburned carbon, but also changes the porous structure and surface properties of unburned carbon.
- One-step activation can increase the surface area of the produced activated carbon from fly ash and anthracite, where the produced activated carbons are not only rich in micropores, but they also present a high content of mesopores.
- The CO<sub>2</sub> adsorption results show that the CO<sub>2</sub> capture characteristics of the activated carbons do not show any clear relationship with the surface area and pore volume.
- Activated carbons with high surface area and microporosity, and CO<sub>2</sub> adsorption capacities can be produced from the unburned carbon treated with boiling HNO<sub>3</sub>.
- The impregnation of PEI can improve significantly the CO<sub>2</sub> adsorption of unburned carbon and its activated counterparts, where the PEI impregnated deashed CC1 sample can adsorb as much as 93.6 mg CO<sub>2</sub>/g at 75°C.

### 5. ACKNOWLEDGEMENTS

The authors wish to thank Combustion Byproducts Recycling Consortium (Project number 01-CBRC-E9) and the Consortium for Premium Carbon Products from Coal (DE-FC26-98FT40350) for supporting this work. The background picture used in this poster is a representation of the future DOE Vision-21 Plant.